Application of Interactive Genetic Algorithm to Fashion Design

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ABSTRACT

In general, computer aided design support systems have got an approach of traditional artificial intelligence, which statistically analyzes data such as the behavior of designer, to extract formal design behavior. This approach, however, can neither deal with continuous change of fashion nor reflect personal taste well, as it just depends on large amount of collected data. To overcome this sort of problem interactive genetic algorithm (IGA) has been recently proposed, as a new trend of evolutionary computation. IGA uses human's response as fitness value when the fitness function cannot be explicitly defined. This enables IGA to be applied to artistic domains, and we propose a fashion design aid system using it. Unlike the previous works that attempt to model the dress design by several spline curves, the proposed system is based on a new encoding scheme that practically describes a dress with three parts: body and neck, sleeve, and skirt. By incorporating the domain specific knowledge into the genotype, we could develop a more realistic design aid system for women's dress. We have implemented the system with OpenGL and VRML to enhance the system interface. The experiments with several human subjects show that the IGA approach to dress design aid system is promising.

Key words : Interactive genetic algorithm; Fashion design; Subjective evaluation; Domain knowledge; User satisfaction; OpenGL

1. INTRODUCTION

One of the biggest changes since the Industrial Revolution is on the market economy. Think about clothes market. Before the Industrial Revolution, consumers had to make their own clothes or buy one from very small producers. Naturally they have few choices on it. However the Industrial Revolution enables mass-production, and now consumers can make their choice from very large amount of clothes. The trend that consumers lead the market is now on progress. Perhaps in the future, consumers can order their favorite design to manufacturer, and then a cloth is produced according to that design [2].

As most consumers are not professional at design, however, a sophisticated computer aided design system

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might be helpful to choose and order what they want. It can be a solution that designer contacts consumers and percepts their favorite design, but it is not efficient in terms of cost and time. Computer aided fashion design systems for non-professional may search out user's preferential design efficiently.

In this paper we develop a fashion design aid system with interactive genetic algorithm (IGA) using domain specific knowledge. We have classified women's dress design into 3 parts, made them as separate 3-D models with OpenGL and GLUT library, and produced individual designs from combination of these models. Through the interaction with user, our system can effectively suggest the nearest design of what user prefers to.

This paper is organized as follows: Section 2 introduces fashion design and conventional fashion design aid systems, and gives an account of IGA. Section 3 describes the overview of the system, genotype encoding, and genetic operators. Section 4 gives 3-D modeling process and system implementation using OpenGL and GLUT library. Section 5 analyzes some experimental results.

2. BACKGROUND

2.1 Fashion Design

The word 'design' is originated in 'designare' of the Latin language, which means 'to symbolize some plan.' The meaning of design has changed age by age. Though it meant only process of planning and organizing in the past, it now means not only to planning but also the result of that plan. Therefore, we can say that 'fashion design' means 'to make a choice within various styles that clothes can take' [24].

Fashion design consists of three shape parts : silhouette, detail and trimming. Silhouette is outline or outlook shape that expresses whole characteristic of a cloth. Detail is composed of subdivided parts of silhouette including neckline, sleeve, skirt, etc. Trimming is a generic term of all finishing ornaments. This paper is focused on detail elements. General details are as follows (see Fig. 1) [15, 18, 19].

- Neckline : Neckline of clothes which is easily in sight, as it is near one's face.
- Collar : A general name of something rolling around one's neck. Normally it is patched on the brim of clothes' neck.
- Sleeve : A detail that covers one's arm. Functionality is highly needed because there is a lot of movement on this part.
- Cuffs : A detail that finalizes sleeve. It often takes a shape of a band.
- Waistline : Central part of a human and also a basis of fashion design.
- Skirt : Independent clothes covering the lower half of one's body, or a part of clothes under waistline.
- Pants : A generic term of men's or women's trousers.
- Pocket : Functional detail that puts something in it. Pocket is also an important ornament.

Fig. 1 General details of female's dress

2.2 Fashion Design Aid System

Though the meaning of design has changed by time, the works that designers do has not changed much when they design clothes. They start with a sketch and flesh it out into an illustration. With clippings from magazines, journals and photographs of similar or rival designs from fashion shows, they make these concepts into some sample pieces. These samples are tested for quality, feel and aesthetics very rigorously. Recently, computer has begun to aid these works.

There are many systems that aid fashion design works. AutoCAD from Autodesk, the famous computer-aided design system software, can be used well for fashion design aid system. The design work can be drastically reduced by using apparel design software or plug-in, such as ApparelCAD, that is designed to work along with AutoCAD [20]. Creative Designer System from Gerber is another solution for fashion design. It is an elaborate graphic workstation with software and some hardware, which can get image and color from sketches, photos, fabrics, or real materials, and edit them by selecting menu [14]. Other general software, such as Photoshop and Illustrator from Adobe, can be used as well as other dedicated fashion design system [13, 17]. Virtual Reality

(VR), which is archived by some computer system, also can reduce time and cost to make and test samples, and throw away one below some level. Laser scanner [5] or digital camera takes one's measurement. The captured body models can be transformed to virtual mannequins, and computer can make them walking just as real fashion models do. User can get finely fitted clothes both as 3D models and as 2D-pattern block representation [11]. These fashion design aid systems work well, but they are usually for professionals only, and it is hard for non-professionals to use.

Some design-aid systems have been developed using Evolutionary Computations (EC). EC is an optimization and classification method having a basis on the theory of evolution. It contains the methods of genetic algorithm (GA), genetic programming (GP), evolutionary programming (EP), and evolution strategies (ES). Fashion design aid system using EC can be used by non-professional person, because it evolves individuals according to interaction with user. Nakanishi developed a fashion design aid system using GP in 1996 [21, 22]. He encoded a number of lengths from a dress into chromosome. The system evolves each dress design according to user's selection. But most of its productions were somewhat impractical, because encoded individuals did not contain realistic knowledge on the domain of fashion.

2.3 Interactive Genetic Algorithm

GA was proposed by John Holland in early 1970s. It applies some of natural evolution mechanisms like crossover, mutation, and survival of the fittest to optimization and machine learning. GA provides very efficient search method working on population, and has been applied to many problems of optimization and classification [3, 9]. General GA process is as follows [7]:

- Step 1 : Initialize the population of chromosomes.
- Step 2 : Calculate the fitness for each individual in the population using fitness function.
- Step 3 : Reproduce individuals to form a new population according to each individual's fitness.
- Step 4 : Perform crossover and mutation on the population.
- Step 5 : Go to step (2) until some condition is satisfied.

Each chromosome is encoded by a bit string, and crossover operation swaps some part of the bit string of parents. It emulates just as crossover of genes in real world that descendants inherit characteristics from both parents. Mutation operation inverts some bits in the bit string at very low rate. In real world we can see that some mutants come out rarely. Fig. 2 shows the way of applying crossover and mutation operations in genetic algorithm. Each individual in the population evolves to getting higher fitness as it goes generation by generation.

Interactive Genetic Algorithm (IGA) is the same as GA except fitness function. In IGA user gives fitness to each individual instead of fitness function. In this way IGA can 'interact' with user, and also can percept user's emotion or preference in the course of evolution. For this reason IGA can be used to solve problems that cannot be easily solved by GA, such as design and art [16, 21, 22, 23, 25]. Fig. 3 compares the processes of GA and

IGA.

Here is an example that shows the advantage of using IGA instead of GA. The goal of fashion design is to make some 'good design' of clothes. We can apply GA for fashion design by initializing the population of individuals encoded from design characteristics, setting and evolving the fitness as 'how good the design of dress is.' However, there is no standard of 'goodness of design,' and it is almost impossible to organize fitness function. Granting it to be possible, it will become useless after being behind the fashion. IGA might be a solution for this. IGA can reflect personal preference or changing fashion, because it percepts fitness directly from user instead of computing using some function [16].

3. SYSTEM DESIGN

Fig. 4 shows the overview of entire system. There is a database of partial design elements. Each design is stored as 3D models. System selects the models of each part and combines them into a number of individual designs. The population is displayed on screen and user gives fitness values to each design. Then, system reproduces the population proportional to the fitness value of each design, and applies crossover and mutation to make the next generation. The results are displayed again in the screen with 3D graphics. Iteration of these processes can produce the population of higher fitness value, namely better designs.
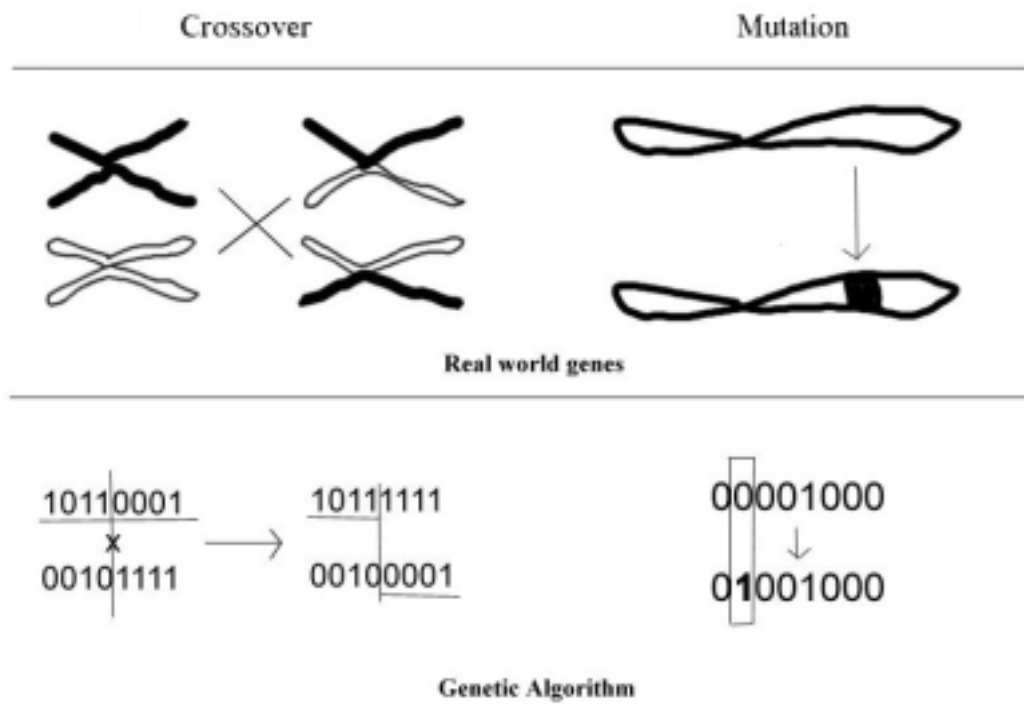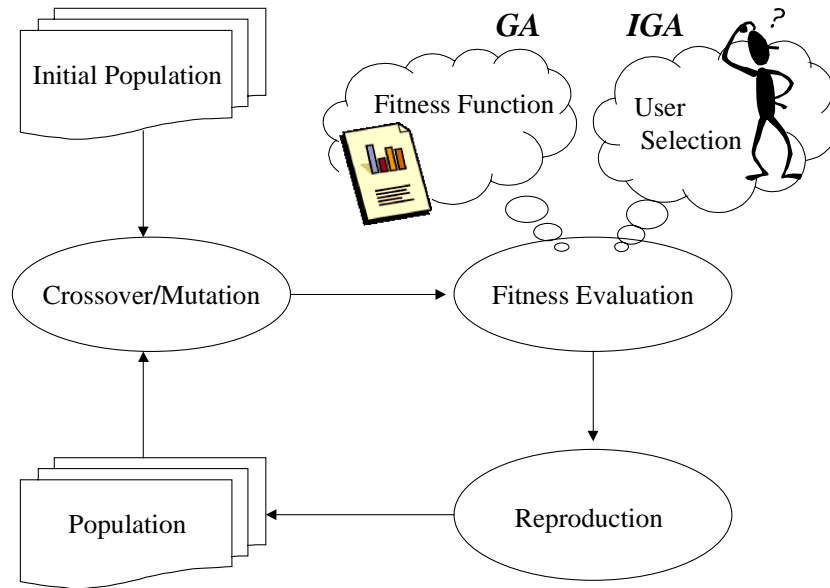

Fig. 2 Crossover and mutation

Fig. 3 GA and IGA processes

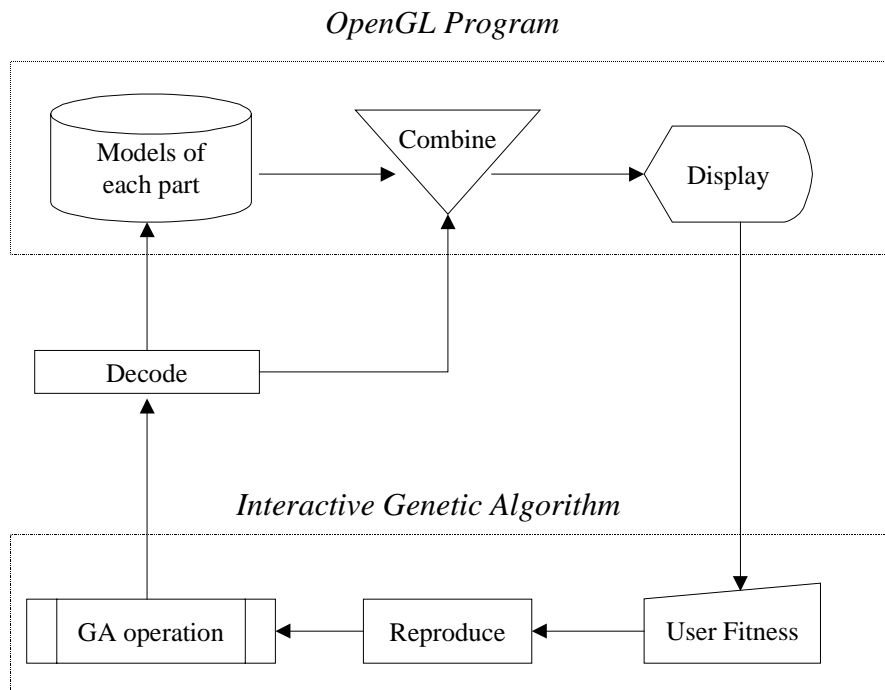*OpenGL Program*

Interactive Genetic Algorithm

Fig. 4 System overview

As mentioned earlier, previous design aid systems using evolutionary computation produce impractical designs because they do not consider domain-specific knowledge. To solve this problem, we have encoded the detail model based on the knowledge of the fashion design. First, we have reclassified general detail factors of Fig. 1 into three parts: neck and body, arm and sleeve, skirt and waistline. Next, we have encoded them with extra 3 bits for each, which chooses the color of each part. A design is made from combining them, and with IGA some combination that produces the design preferred by user is found out, resulting in more realistic and reasonable design. Encoded detail parts are described as follows.

- Arm and sleeve part contains sleeve and cuffs detail. There are 12 models including armless design, and encoded into 4 bits (see Fig. 5).
- Neck and body part includes neckline, collar, and body shape. We have collected and encoded 34 models into 6 bits (see Fig. 6).
- Skirt and waistline part includes waistline and skirt below it. We have collected and encoded 9 models into 4 bits (see Fig. 7).

Each part can take their own color out of 8 colors. Therefore, additional 9 bits are needed to complete chromosome encoding. Fig. 8 describes how a chromosome is completely encoded. We can calculate the size of search space easily by computing all the combinations of design and their colors. The size of search space is 1,880,064 resulted from $34 \times 8 \times 12 \times 8 \times 9 \times 8$. The system searches the best designs out of 1,880,064 candidates according to user's feedback on preference and emotion.
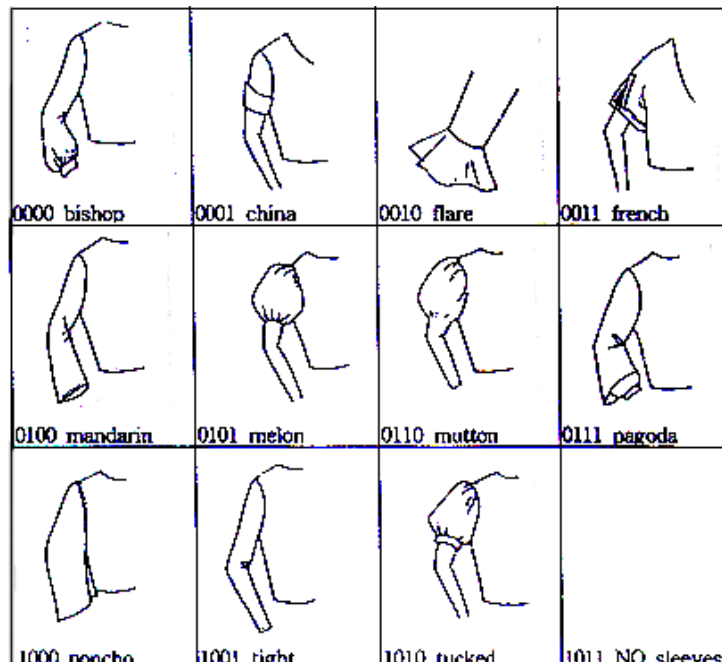

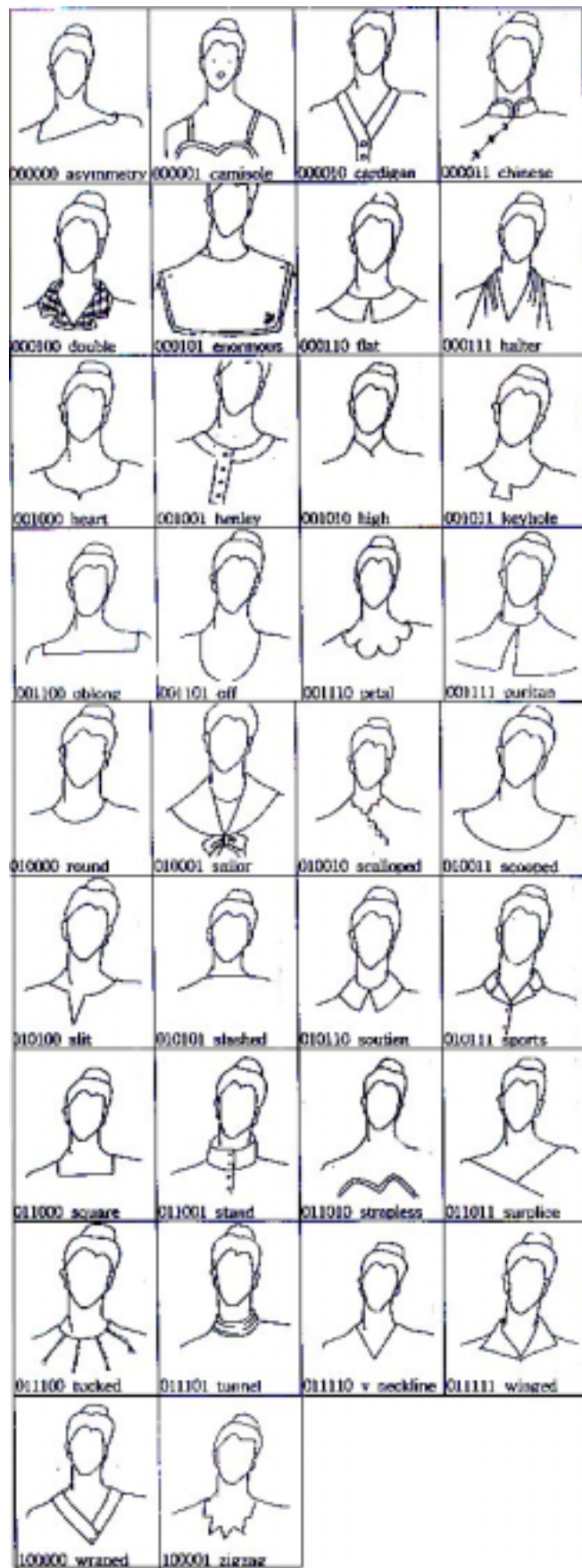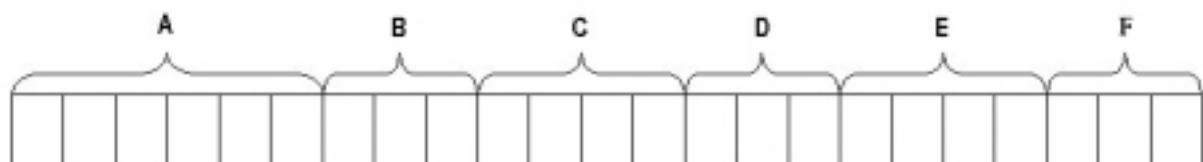Fig. 5 Encoded arm-and-sleeve styles

000000 asymmetry	000001 camisole	000010 cardigan	000011 chinese
000100 double	000101 enormous	000110 flat	000111 halter
001000 heart	001001 henley	001010 high	001011 keyhole
001100 oblong	001101 off	001110 petal	001111 puritan
010000 round	010001 sailor	010010 scalloped	010011 scooped
010100 slit	010101 slashed	010110 soutien	010111 sports
011000 square	011001 stand	011010 strapless	011011 surplice
011100 tucked	011101 tunnel	011110 v neckline	011111 winged
100000 wraped	100001 zigzag		

Fig. 6 Encoded neck-and-body styles

Fig. 7 Encoded skirt-and-waistline styles

Total 23 bits

A : Neck and body style
B : Color of neck and body
C : Arm and sleeve style
D : Color of arm and sleeve
E : Skirt and waistline style
F : Color of skirt and waistline

Fig. 8 Chromosome encoding

4. SYSTEM IMPLEMENTATION

At first, each component of design parts should be created as 3D models. We have used 3D Studio MAX R2.5 for this work, and Fig. 9 shows an example of the 3D modeling. Each model is converted into OpenGL lists [27]. There are two alternatives we can make to show 3D models : VRML and OpenGL. The former is much easier to show 3D models, but it is too slow and drops modeling quality a little bit [1]. OpenGL is faster than VRML but it demands far more time and efforts to implement the system. Due to this reason we use OpenGL library from SGI with GLUT library developed by Mark Kilgard and ported to Win32 by Nate Robins [12].
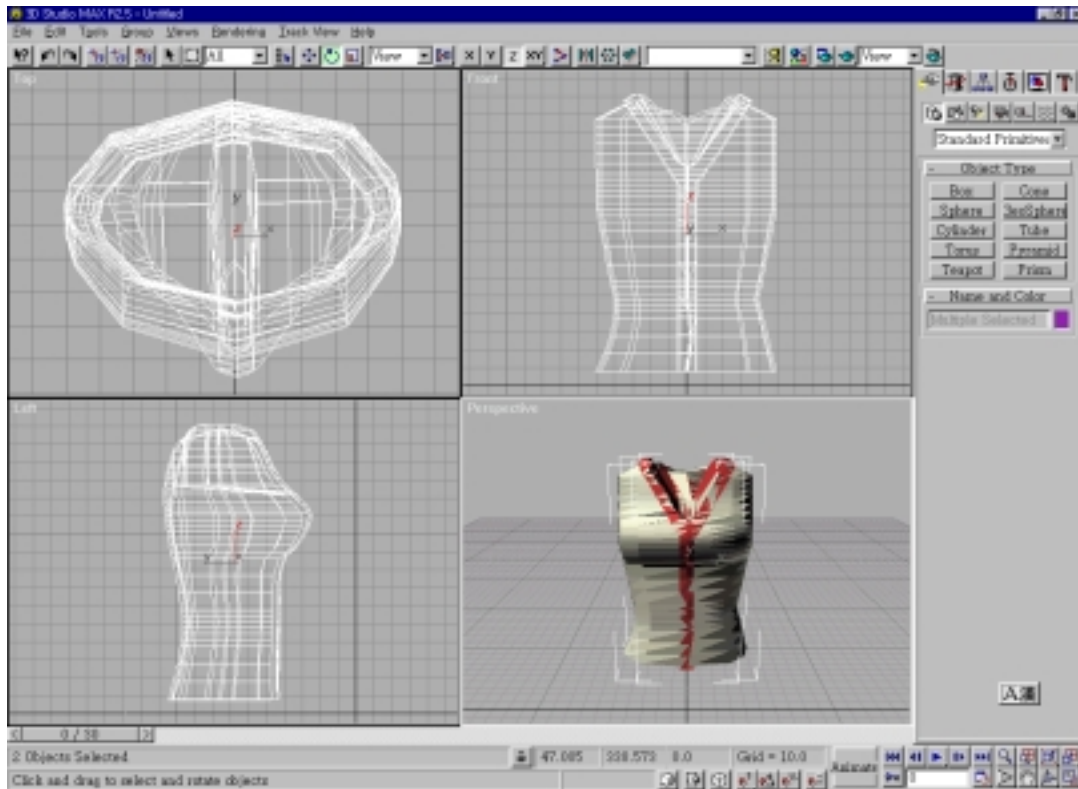

Fig. 9 3D modeling with 3D Studio MAX

Converted models are inserted into C program, written in Visual Studio 6.0 of Microsoft. The system can show combined 3D models through OpenGL operation, according to decoding from individual genotype. Fig. 10 gives an example of combining models from genotype bit string. Fig. 11 shows the user interface of our system. The system shows current population composed of 8 individual models in one screen. There is a slider bar for each individual design to obtain user's feedback or preference. The rightmost part of screen shows the current status of evolution, and provides the controls 'to generate next population' and 'to restore previous population.' One can find out their favorite design from the large search space by interacting with the system.
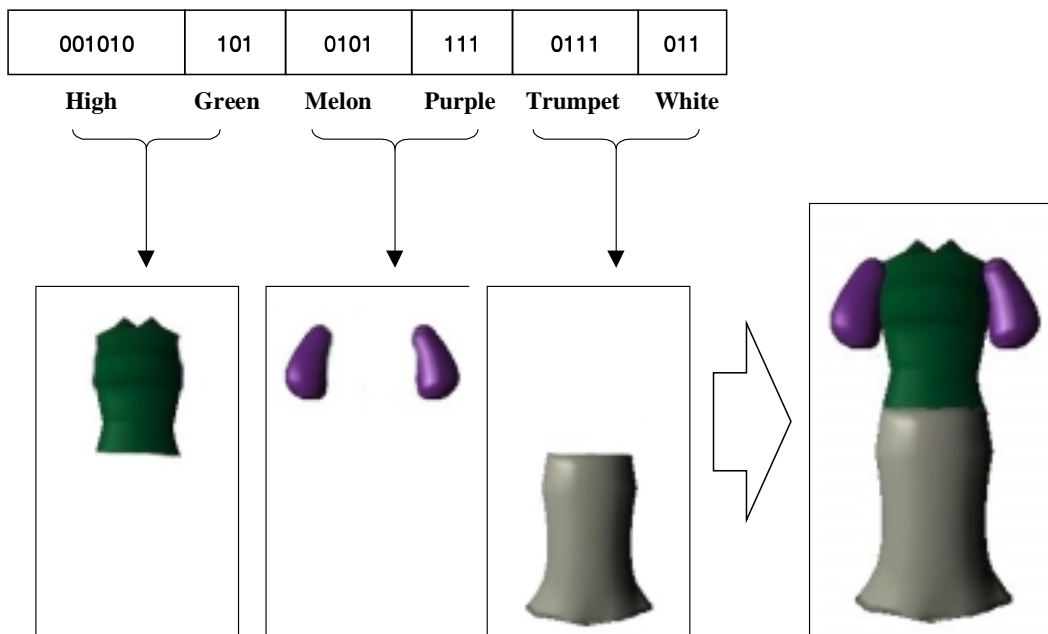
001010	101	0101	111	0111	011

High   **Green**   **Melon**   **Purple**   **Trumpet**   **White**

Fig. 10 Decoding from example genotype

Fig. 11 User interface of the system

5. EXPERIMENTAL RESULTS

5.1 Environments

The system runs on Pentium PC. For each experiment, the population size is 8 and the number of generation is limited to 10. We have used one-point crossover of 0.5 and mutation of 0.05. As a strategy of evolution, we have preserved one elitist individual in each generation for the next generation. To evaluate the performance of this system, we have carried out convergence and subjective tests.

5.2 Convergence Test

It is difficult to show the convergence of IGA with quantitative analysis because it is operated based on human's evaluation. Fig.12 shows the evolution process of an individual with the corresponding chromosome, in searching for designs of cool feeling. (c), the offspring of (a) and (b), tends to give cooler feeling than (a) and (b). To show the convergence of the method as an experimental result, we have requested 10 subjects to find cool-looking design and splendid design using the system. Fig. 13 shows the changes of fitness on average and the best, while subjects are searching cool-looking design. Fig. 14 shows the changes of fitness with the splendid designs searched. Though the search space is extremely large, these figures show the steady improvement of the result over generations. Fig. 13 shows faster convergence than Fig. 14, because the meaning of 'splendid' might be more complex and various than that of 'cool-looking.'
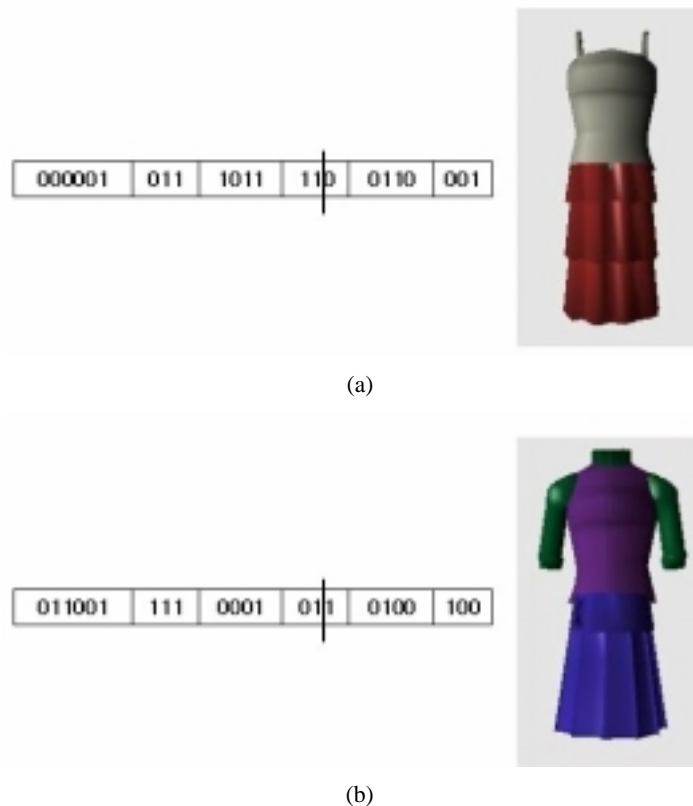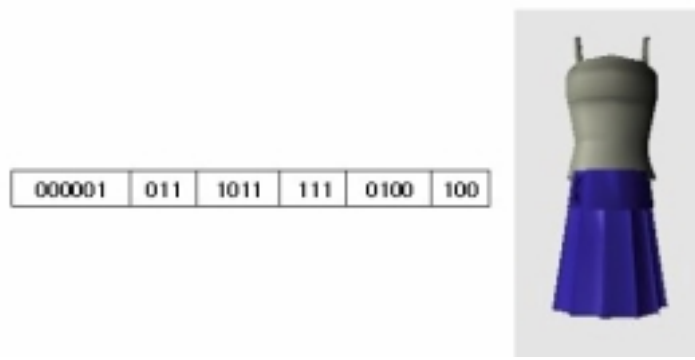

(a)

(b)

Fig. 12 (Continued)

(c)

Fig. 12 Chromosomes and the corresponding designs. (a) and (b) are two parents and show a crossover point, and (c) is the offspring generated by applying crossover to (a) and (b).
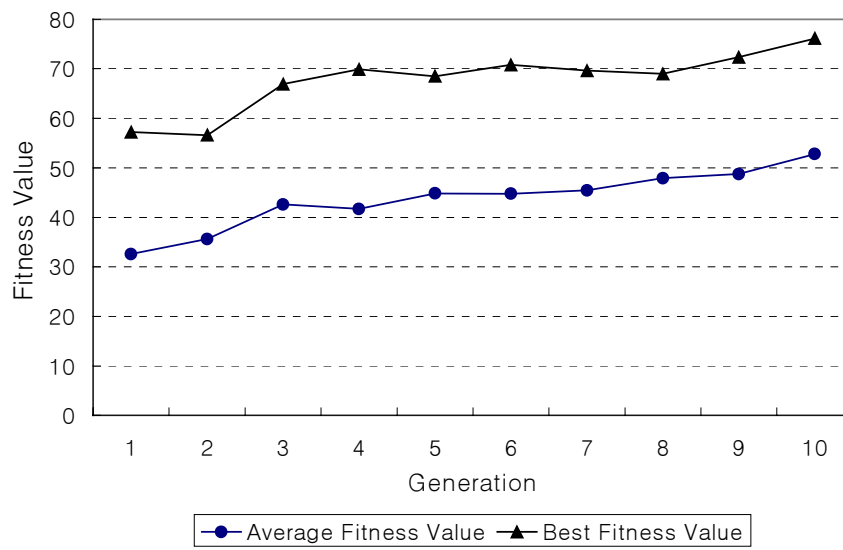

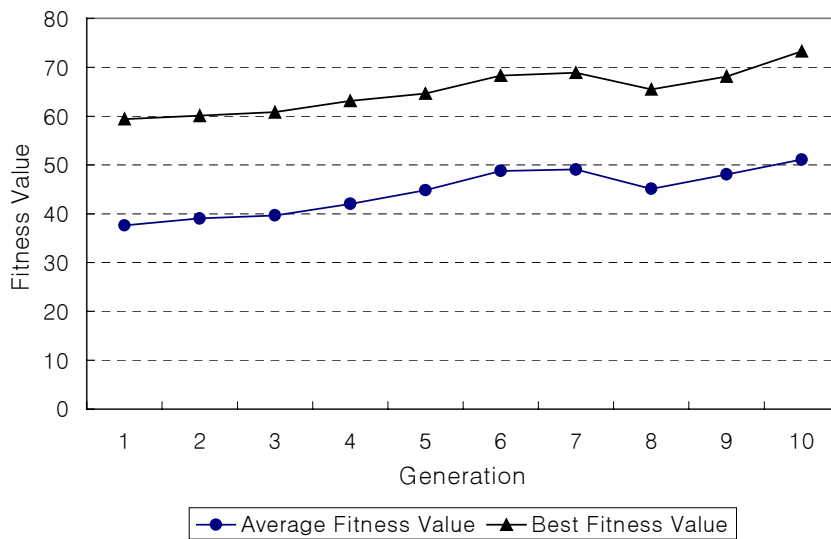Fig. 13 Fitness changes on searching for cool-looking design

Fig. 14 Fitness changes on searching for splendid design

5.3 Subjective Test

This test shows how much the user is satisfied with the system performance. We have used pair-test of Sheffé [6]. It prevents users from evaluating searched design too subjectively by requesting them to compare each design with some relatively objective ones, pair to pair.

First, we have randomly selected 500 sample designs from entire search space, and requested 3 subjects to evaluate the sample designs with 2 categories, coolness and splendor, into 5 degrees (from –2 to 2). From their average scores, 10 most cool-looking designs and another 10 most splendid ones are selected as standards of evaluation.

Next, we have requested 10 subjects to find cool-looking design and splendid design using the system. Each searching is limited to 10 generations. After 10 generations, subjects must select the best one from the last population (Fig. 15 shows some examples), and compare it with the standards we made before, pair to pair. This score has 7 degrees (from –3 to 3). Finally, the result is analyzed statistically. Fig. 16 shows the degree of user's satisfaction at 95% and 99% of reliability. Subjects have given 2.17 to the design searched for cool-looking design and 1.74 for splendid design on average. It can be seen that searching for cool-looking design has gained higher satisfaction score, and shows narrower confidence interval.

We can assert that subjects are significantly satisfied with the system on searching for cool-looking design and splendid design. Therefore, applying IGA to the fashion design aid system for non-professionals is very promising.

Fig. 15 Examples of searched design which gives cool feeling

Fig. 16 Mean of satisfaction degrees

6. CONCLUDING REMARKS

We have proposed and developed an IGA-based fashion design aid system for non-professionals. Unlike previous systems, we have made use of domain specific knowledge to encode genotype with OpenGL design models, which provides us with more realistic and reasonable design. For the problem of searching in a huge search space, IGA has helped searching by providing effective incorporation with human preference and emotion.

To test the performance of the system developed, we have conducted convergence and subjective tests. The result shows that users are significantly satisfied with searched designs by interacting with the system, thereby applying IGA to the fashion design aid system seems appropriate. However, there remain two major points to improve.

First, the search space should be enlarged. Currently the size of the search space is 1,880,064. Though it is not small, we should expand the search space because there are a lot of design elements that have not been considered yet. Especially we should encode the 'textile' of clothes as new parameter. Textile means the feel of texture, the pattern on texture, the softness of material, and so on. It is an important design element because almost all the clothes have characteristics of their textile, and it makes a great impact on the feelings for entire design. As OpenGL and GLUT library supports textile, it will not be difficult to encode textile design.

Second, we should solve the genetic drift problem caused by the small size of population. One possible solution is to make clusters of population and approximate the fitness of individuals from representative in the same cluster. Clustering refers to the process of grouping samples, which are similar within each group [4, 8, 10] called cluster. In IGA clustering can be used to keep large population without any increase of user's burden to assign fitness.

Multi-field user interface with migration model [26] can be a solution as it keeps diversity even with a small population of IGA. Multi-field user interface emulates migration of island model. After geographical separation of a continent into islands, a population of species that lived in a continent is divided into sub-populations in each island, and they reach usually distinct organisms through independent evolutionary process. The mating

between different islands is prohibited and there are many sub-optimal points for the structure of an organism. We can expect to get better solutions by migration of individuals among different islands after reaching some convergence.

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